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MAINTAINING THE DEFENSE INDUSTRIAL BASE

by

Ted F. Bowlds
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A RESEARCH REPORT SUBMITTED TO THE FACULTY
IN
FULFILLMENT OF THE CURRICULM
REQUIREMENT

Advisor: David Blair

MAXWELL AIR FORCE BASE, ALABAMA

May 2, 1994

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ABSTRACT

TITLE: Maintaining the Aerospace Industrial Base

AUTHOR: Ted F. Bowlds, Lieutenant Colonel, USAF

The demise of the Soviet Union marked the "official" end of the Cold War with the United States the clear winner. For the defense industry, this has accelerated the reductions in spending. The impact is a smaller industrial base with far less capacity. Employing new manufacturing technologies while reducing the government regulatory burden will keep the industry viable for potential future needs.

BIOGRAPHICAL SKETCH

Lieutenant Colonel Ted F. Bowlds (M.S. in Electrical Engineering from the Air Force Institute of Technology and a M.S. in Engineering Management from the University of Dayton) has spent most his career in systems acquisition. This has included work on the F-117 as a flight test engineer and avionics branch chief in the B-2 program office. Most recently, LtCol Bowlds worked in the Pentagon for the Assistant Secretary of the Air Force for Acquisition as the Chief of the Bomber Branch.

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Chapter I
INTRODUCTION

"Although most history books glorify our military accomplishments, a closer examination reveals a disconcerting pattern: unpreparedness at the start of a war; initial failures; reorganizing while fighting; cranking up our industrial base; and ultimately prevailing by wearing down the enemy—by being bigger, not smarter."

General David Jones

The demise of the Soviet Union marked the "official" end of the Cold War, with the United States the clear winner. The reward for this victory is the "peace dividend," and producing it requires a partial dismantling of the U.S. defense infrastructure. While the degree of dismantling is unclear, it impacts two parts of the national defense. The most visible part of this dismantling is the reductions in existing military personnel, bases, and equipment. These reductions in infrastructure impact the current force structure and the existing warfighting ability of the United States. Specifically, the number of personnel and the quantity of equipment in the inventory relates directly to the size of conflict in which the U.S. can comfortably engage.

The second part of the defense dismantling is the downsizing of the defense industrial base. As the U.S. scales back its existing force structure, the demand for spares and replenishments is also lessened. This reduced demand diminishes the output requirements placed on the defense industry. The defense industry's reaction is fewer workers and fewer suppliers. Additionally, in the environment of a "safer world," there is a reduction in the advocacy and need for newer weapon systems. This causes shorter production runs, a constant change in the quantity required, or in some cases, canceled programs altogether. The reduction in the B-2 production quantity from 132 operational aircraft, to 72 aircraft, and eventually to 20 occurred in just such an environment. This lack of a perceived threat also impacts the willingness of the government to explore new technologies.

The net effect of this dismantling is a reduction in the deterrent capability of the military. Marvin Leibstone writes in Military Technology that "The demobilisation of military assets, coupled with cutbacks in defense equipment production, freezes combat capabilities...For the nation cutting back its military assets and equipment replenishment capacity, the opportunity to widen the window of any recent military victory into a deterrent for a wider window of peace, is lost. In effect, military modernisation as an instrument of peace, hits a wall."[1]

There is a debate about whether reductions in force structure or industrial capacity are most detrimental to the national security. No attempt will be made to justify either side of the argument rather suffice it to say that both are seeing reductions under current budget constraints. This paper will, however, focus on the impacts the reductions are having on the industrial capacity and will recommend steps that can strengthen this capacity during future reduced budgets. In order to insure the industrial base can support future defense needs, there needs to be fundamental changes in the approach to the business of defense.

Developing this prescription for maintaining the defense industrial base involves a two step process. First, it is important to establish the current status and expected future condition of the industrial base. The industrial base has been in decline for a number of years and the end of the Cold War has accelerated this decline. These reductions are changing the complexion of the defense industry; fewer contractors, limited suppliers, and reduced capacity. Coupled with this decline are the increasing demands placed upon the military in support of emerging foreign policy. Taken together there is less opportunity to maintain a large defense base.

Having established the industrial base's current and future situation, the next step is to define a recommend course of action. This recommendation involves two key elements. First, the industrial policy of the U.S. must insure the continued

advancement of technology. Advanced technology weapons have been the hallmark of the U.S. military and there is no reason to abandon this approach. Second, the industrial capacity must have the potential to support the U.S. needs in time of crisis. Specifically, an existing production line is easier to accelerate than one that does not exist. Additionally, an existing production line also provides the framework from improvements in manufacturing technology can be explored. This production capacity, when coupled with improvements in manufacturing technology and reduced government regulations, will improve efficiency and reduce overall spending.

Chapter II
CURRENT NEED AND STATUS

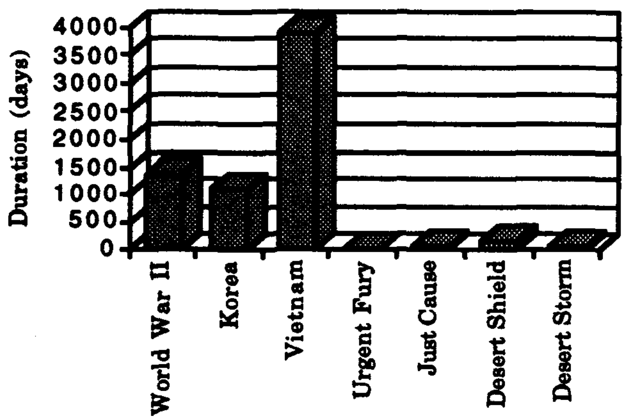
In a protracted conflict or following a short engagement, the nation relies on its industrial capacity to rearm and rebuild the military. The dismantling of this industrial capacity has a much longer term impact on the national military strength. As the resources (funding) to support future acquisitions diminish, the industrial infrastructure also decreases. Reductions in research, development and procurement are used to maintain the existing force structure. A recent study determined that acquisition accounts are "more heavily affected by budget authority changes than non-acquisition." They are as much as 3.2 times as sensitive.[2] Stated another way, reductions in the defense budget have the greatest impact on procurements.

The current and future status of the industrial base is best described by three aspects. First, since Vietnam, the United States participation in conflicts has been of short duration. The American people and Congress have developed a dislike for protracted wars. Their preference is for quick, decisive actions. Second, since 1989 there has been a precipitous decline in the number of large manufacturing facilities, as well as in the subcontractor base that supports these large facilities. The number of aerospace manufacturing facilities in existence today has decreased to a level that prevents large-scale, quick reaction. This decline also adversely affects the ability of the industry to support existing forces with spares and replenishments. Finally, the time required to place a major weapon system into service has grown steadily. The time from initial concept to first production delivery is now more than ten years for advanced weapon systems. Taken together, these aspects illustrate the need to change our current approach to weapon system acquisition.

Future Conflict Duration Trend

At the center of the defense industrial capacity is the United States experience and participation in conflicts. These experiences form the foundation for future expectations. Based on the experiences since Vietnam, future conflicts will be regional in nature and of short duration. Support for this expectation starts with an analysis of the duration of past conflicts. The arbitrary starting point for this analysis is the Second World War. Figure 1 illustrates the duration of major U.S. conflicts since World War II.[3]

Figure 1: Past U.S. Conflict Duration



It is readily apparent from these data that Vietnam was the last long-duration conflict for the United States. Since Vietnam, the major conflicts have been short, typically less than six months long. Today, the U.S. is involved in lengthy peacekeeping commitments that seem to contradict this trend. However, in reality these peacekeeping efforts also support this trend. First, the number of personnel involved in peacekeeping exercises is relatively small. While these exercises require lengthy involvements, the going-in proposition, and the main reason for U.S. support, is to reduce the likelihood of a protracted conflict. If peacekeeping efforts should fail, the U.S. approach to the subsequent conflict involves overwhelming force, a force which has both numerical and technological superiority. Therefore, it

is reasonable to characterize future conflicts involving the U.S. as short-duration involving overwhelming numbers of forces.

This difference in duration also highlights a side benefit realized only in longer conflicts. The longer-duration conflicts saw the introduction of new, revolutionary technologies. In World War II the most notable was the development of the atomic bomb. President Roosevelt approved the atomic bomb project on 9 October, 1941. It would take until 1945 before the Manhattan Project produced workable "prototypes." On 6 August, forty-six months after the project's initiation, the Army Air Forces dropped the first atomic bomb on Hiroshima.[4]

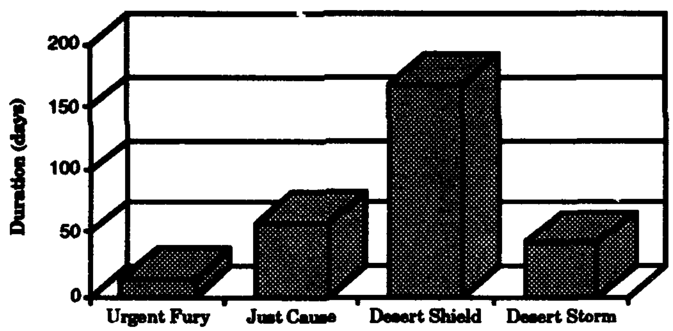
Vietnam saw a similar experience in the development and deployment of laser guided bombs. The U.S. Army Missile Command began experimenting with laser guidance for munitions in 1962. The Army shared this initial work with the Air Force in 1965. It would take three years before the concept received operational testing in Vietnam. By 1969 laser guidance kits and designator pods were available in sufficient numbers to see wide usage in Vietnam.[5] Using the Air Force's initial involvement as the starting point, it took three years before a working prototype was available for evaluation.

The Gulf War saw the use of many advanced technologies, such as Global Positioning System and stealth (F-117) as well as prototype technologies like the Joint Surveillance and Target Acquisition Radar System (JSTARS). However, these advanced technologies had been in existence several years before the Gulf War. The F-117s saw use in Operation Just Cause and the developmental JSTARS first flew on April 1988. There are some examples of new programs introduced during the Gulf War. The most noteworthy was the GBU-28 laser guided bomb. Developed, built, tested, and used in combat in a 17-day period, the GBU-28 was the marriage of several off the shelf technologies (existing laser guidance packages and naval gun barrel).[6] Unlike the developments that occurred during World War II and Vietnam,

the GBU-28 was more an engineering integration exercise than revolutionary technology. As such, these future short-duration conflicts will not see the development and introduction of new weapon systems. Rather, future conflicts will take place with the equipment existing in the inventory.

Viewed separately the duration of conflicts since Vietnam illuminates another key factor. Figure 2 shows the duration of conflicts since Vietnam. The actual duration of the fighting in these three conflicts is less than approximately fifty days. When one considers the deployment to and the return from a conflict, the actual length of fighting is short. Additionally, the preparation time of Desert Shield more than overshadows the actual fighting in Desert Storm. Therefore, the bulk of future conflicts will probably involve the deployment of resources vice actual combat.

Figure 2: Conflict Duration Since Vietnam



Today, regional contingencies throughout the world involve the United States, mostly in the role of peacekeeper. Any of these contingencies could erupt into a regional conflict. If that happens, based on the experiences of the United States, the U.S. involvement will utilize the existing equipment in overwhelming numbers. The goal for the U.S. in these potential conflicts is for a short duration.

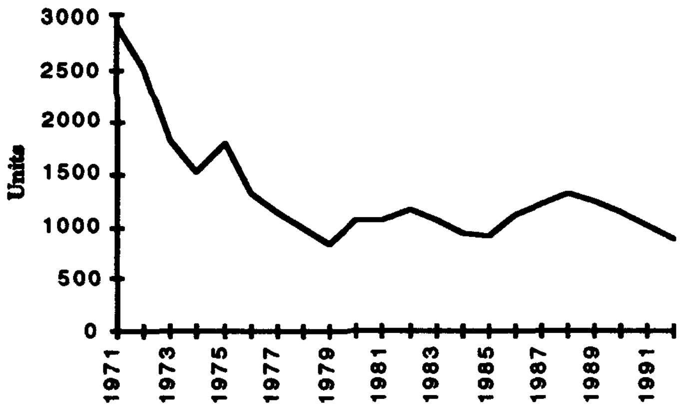
Decline in Manufacturing Capacity

The reduction in the defense department budget has forced a similar decline in the defense industry's capacity. Two characteristics typify this decline. First, there

is a real reduction in the industrial capacity of the aerospace industry. This reduction means fewer suppliers and fewer manufacturers. Second, the decline forces the industry to consolidate its excess capacity. As DoD finds it more difficult to fund programs "beyond the development stage, the trend toward teaming among companies is accelerating to reduce market and technical risk."[7] Each of these impacts presents a unique challenge to maintaining the U.S. industrial capacity and providing support to the military.

The end of the Cold War did not mark the start of the decline in U.S. aerospace industrial capacity. As shown in figure 3, since 1971 the deliveries of military aircraft has decreased steadily.[8] Coupled with this reduction in deliveries is a similar decrease in people and companies involved in the aerospace industry.

Figure 3: Military Aircraft Shipments



From 1989 to 1991, more than 50,000 jobs disappeared from military aircraft plants.[9] This number could reach 500,000 by 1995.[10] In Los Angeles County alone "aerospace employment fell by 61,600 jobs from 1987 to 1991, a loss of 20.8%."[11] This loss in workforce is significant because it represents a true loss in talent. Aerospace manufacturing jobs require special skills. Some of these skills are unique to the aerospace industry. As an example, the use of synthetic composites in the aerospace industry has dramatically increased. The skills required to work with advanced aerospace composite materials are unique to the industry. Developing

proficiency in this work takes time, called learning curve. The loss of these jobs translates into an increase in learning curve for the workforce. This means an increase in the manufacturing start-up time for a new programs.

Coincidental with the job loss is the reduction in manufacturing facilities. From 1982 to 1990, "the number of U.S. firms making hardware for the Pentagon plummeted from 120,000 to only 40,000."[12] According to the Small Business Administration, in 1988 approximately 4,000 small defense firms went bankrupt.[13] It is the loss of these small firms that is most alarming. The large aerospace companies like Northrop and General Dynamics rely heavily on these subcontractors as a source of individual parts. Loss of these firms requires the development of alternative sources and this, in turn, increases manufacturing time.

Small firms are not the only ones impacted by reducing the manufacturing capacity. Using Los Angeles county as an example, a recent task force reported:

> "Of the thirteen aircraft developed or produced in the County during the 80's, only two, the B-2 (its production has recently been cutback to 20 planes) and the C-17 are still active. There is only one major military aircraft program on the drawing board until well into the twenty-first century. As a result, military production in Los Angeles County may conclude upon completion of the C-17 program."[14]

The initial response of the aerospace industry to the decrease in work has been to consolidate its resources. Some, such as former Secretary of the Air Force Donald B. Rice, have stated that the industry has an excess in capacity. However, the trend is for major contractors to enter into joint ventures.[15] There are two sides to this consolidation. Joint ventures reduce duplicate capacity making the industry more efficient. The B-2 is an example of a joint venture; Northrop is the prime contractor with Boeing and LTV utilized as major subcontractors. Each contractor brings to the B-2 a unique manufacturing capability not duplicated at the prime's facilities. Viewed in this light, consolidation makes good business sense.

Alternatively, consolidation eliminates duplication that impacts the ability of the industry to react quickly. Those contractors possessing a unique capability could

become a bottleneck in the production of several weapon systems. Additionally, the industry's consolidation increases vulnerabilities since only one contractor may own essential skills and/or facilities. This also places the government into a sole source environment for critical components which has the potential for increased costs.

In some extreme cases of industrial capacity downsizing, technologies are only available from overseas suppliers. "Dependence on foreign suppliers is increasing, particularly for computer chips, machine tools, bearings, and optics."[16] Foreign dependence for critical defense components also increases the vulnerability of the United States.

In the near future, the defense industrial base can be expected to continue adjusting in size according to the prevailing market forces. The recent merger between Northrop and Grumman is indicative of this adjustment. Rather than downsizing, some have referred to this type of adjustment as "rightsizing" the defense industry.[17] As the needs of the defense department continues to decline, some adjustment in the industry will also occur.

The loss of skilled labor, the elimination of the contractor base, and a growing dependency on imports increases the risk of providing timely support to the U.S. defense needs. There have been some attempts to coherently resize the industry through joint ventures, but the overall impact on the defense industry is a reduced capacity to respond.

Time to Develop and Field New Systems

The final aspect that demonstrates the mismatch between industrial capacity and defense needs is the time required to develop and field new weapon systems. Increasing an existing program's production rate, such as the F-16, is realistic in time of need. For a new threat, however, the time required to place a new counter-

system into the hands of the operators may far exceed the demand. Two examples and general historical data illustrate this point.

One of the preeminent weapon systems of the Gulf War was the F-117A, the world's first operational stealth aircraft. The F-117A could attack targets deep inside Iraq with little or no support (electronic countermeasure aircraft, few tankers than a conventional air strike package, and air superiority fighters). The idea for a radar-avoiding aircraft was an outgrowth of the Vietnam experience. The skies over heavily defended Hanoi stressed conventional countermeasures systems. In 1974 the Defense Advanced Research Projects Agency requested proposals for a stealthy fighter demonstration program under the project name Have Blue. Lockheed was awarded the demonstration program contract in 1975. The first Have Bl testbed flew in December 1977.[18] Lockheed built two testbed aircraft: both cras one in 1978 and the other in 1980.[19]

By 1978 however, flight testing proved the viability of stealth, and in November of that year, the Air Force awarded Lockheed the production contract for the F-117A. Slightly different in design from Have Blue, the first flight of the F-117A occurred on June, 1981.[20] It would take another two years of testing, development, and production before declaring the first F-117A squadron operational (October, 1983).

Viewing the F-117A program from its Have Blue inception in 1975, it took eight years to achieve an initial operational capability. One of the primary reasons for this "fast" development time was the nature of the program. The F-117A was a covert, or "black," program. This eliminated much of the management oversight that would have slowed the development by introducing additional review requirements. Additionally, the F-117A is predominately an aluminum aircraft covered with radar-absorbent materials.[21] This allowed Lockheed to use conventional aircraft manufacturing techniques.

The other end of the development spectrum is the F-22. The initial contract award for demonstration/validation phase occurred October 1986. Two contractors, Lockheed and Northrop, competed during this phase. Lockheed's prototype first flew in August, 1990, and ultimately won the competition. The initial prototype test program continued until 1992. The F-22 is now in final production design and manufacturing. The aircraft is being updated with refinements identified during the initial prototype test program. The first flight of the engineering manufacturing development aircraft is scheduled to occur on June, 1996. The first production delivery is scheduled for January, 2000.[22]

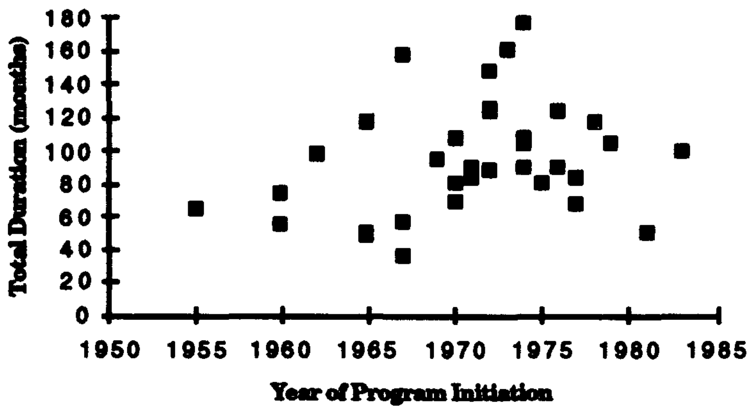
Using a start and end point similar to those of the F-117, the F-22 program will take at least fourteen years before delivery of operational aircraft. This is significant, given the rate of technology evolution. When the F-22 begins to make its appearance at Air Force bases in the year 2000, it will employ technology developed in the early 1990's. It is inevitable that the first operational F-22's will utilize technology that is ten years old. "On average, DoD now takes more than 17 years to bring a new system into production, putting it in danger of producing and deploying obsolete weapons."[23]

This increased time to develop and deliver operational aircraft is not an isolated case. As illustrated in figure 4, the trend is towards increased program duration with an average developmental time of eight years.[24] (For this data, "total program duration is measured as the time between program start (Milestone I or equivalent) and first operational delivery."[25]) This trend will continue as aircraft designs increase in complexity.

In years past, lengthy developments did not present as big of a problem as today. The Cold War saw many developmental programs whose very existence provided a measure of deterrence. A good example is the Strategic Defense Initiative or "Star Wars" program. Today the world is much more volatile. Contingencies arise with

little regard for the potential impact of systems in development. Additionally, the rate of introduction of newer technologies causes some designs to be obsolete when finally introduced. In summary, a production program in existence, vice one in the developmental stage, is the best insurance against a potential need.

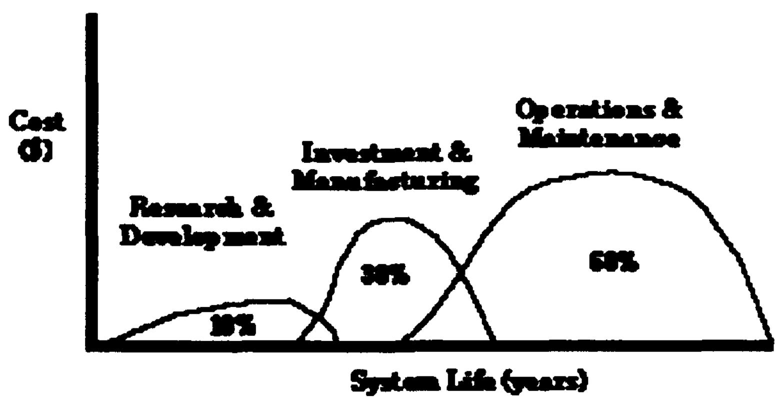
Figure 4: Schedule Trends



Chapter III
REORGANIZING FOR THE FUTURE

Even in times of decreasing budgets and the dismantling of the U.S. military, there remains a requirement to preserve the defense industrial base. Preserving the industrial base requires an investment in those costs associated with weapon system development, procurement, and employment. There are three basic costs associated with weapon systems. As shown in figure 5, these costs are research and development (R&D), investment / manufacturing, and operations / maintenance (O&M). Addressing O&M first, these costs are part of the current military infrastructure. Reductions in these costs affect military readiness and if not properly managed can lead to a "hollow force." The other two costs, the subject of the remainder of this paper, are central to the preservation of the defense industrial base. Two themes describe this preservation.

Figure 5: Weapons System Acquisition Costs



First, the approach used must assure a continuation of the technological lead enjoyed by the U.S. military. Advanced technology vice large quantities of "average" weapon systems continues to be central to U.S. doctrine. The use of the F-117A during the Gulf War is a perfect example of this philosophy. Representing only 2.6% of the Desert Storm attack aircraft[26], the F-117 performed 81% of the precision

strikes against leadership and telecommunication targets.[27] As the U.S continues to reduce the size of the military, this dependence upon advanced weapons will increase. Technologically advanced weapons are a force multiplier for a smaller sized military.

The other theme focuses on maintaining the defense industrial base. If the U.S. is to expect the defense industry to be able to respond in time of need or crisis, the industry must be a viable enterprise in time of peace. This means maintaining an acceptable level of manufacturing capacity that will support expected need. To do this, the industrial base needs to have some level of manufacturing capability while exploring ways to make that capability more cost efficient, flexible, and productive. Additionally, it is important to advance manufacturing technologies and techniques. The government must begin to invest more in the updating of existing manufacturing facilities. "DoD spends about $35 billion a year on R&D, almost all of it for designing new products with improved performance. A tiny fraction, about 1 percent, is devoted to lowering the cost of weapons and improving their quality through process improvements."[28]

Continuing Technology Advancement

The R&D associated with weapon system development helps continue the advancement of technology. It is through this R&D that the U.S. government promotes technology advancement. Doing so not only helps the military, but also promotes technology advancements in the civilian sector. The characteristic separating future R&D from that of yesterday is the reduced opportunity to move the technology directly into production. The projected reductions in the amount of defense dollars means fewer technologies will find their way into production. "With fewer new system starts, investment in technology has its greatest payoff in pushing development to the very edge of making a system decision. The intent will

be to carry technology further along in the technology base, rather than prove it after a decision to build a weapon system."[29]

Unlike technology research performed during the Cold War, however, user needs will guide research in the future. User requirements can be integrated into research efforts in two methods. The first method, as suggested by the Technical Strategy for the Industrial Base working panel at Aeronautical Systems Center, utilizes published "multi-customer-approved mission area development plans."[30] These plan look out 20 to 25-years in advance and provide a long range focus for laboratory research. The second method is a periodic review of on-going research initiatives. This review is conducted by both developers and users. When used in concert, these methods will help ensure a proper technological research focus while providing a mechanism for canceling unnecessary efforts.

Assuming a properly focused research effort, there are two vehicles for continuing the advancement of technology. The first approach uses prototyping to demonstrate the potential of new technologies and potentially field limited quantity unique systems. The second approach stimulates the industrial sector by realizing that R&D is important and increases the profit margins allowed companies.

Prototyping

Prototyping is synonymous with the term rollover that is also used to describe this approach to R&D. Before discussing this approach, it is important to first define prototyping. The best definition for prototyping is offered by the RAND Corporation:

> "A prototype is a product (hardware and/or software) that allows hand-on testing in a realistic environment. In scope and scale, it represents a concept, subsystem, or production article with potential utility. It is built to improve the quality of decisions, not merely to demonstrate satisfaction of contract specifications."[31]

Important in this definition is what a prototype is not. "A prototype is not a complete system in the sense of being deployable to operational forces."[32]

Prototyping provides a stepping stone between a paper idea and physical reality. The Have Blue program mentioned earlier is an excellent example of what prototyping offers. The Have Blue program proved that radar detection could be avoided with a full-scale stealthy aircraft. It took a lot more development before that concept was operationally usable.

Equally important is what constitutes a prototype. Using RAND's definition, a prototype is "a concept, subsystem, or production article with potential utility." Without building the full-scale Have Blue aircraft, the inaccuracies inherent in laboratory experiments call to question the effectiveness of the technology. In the future, not all concepts will see the level of system integration exhibited by Have Blue. Some may never progress past laboratory demonstration nor should there be any guarantees that all ideas would progress to a full-scale prototyping stage.

Prototyping is primarily a mechanism for advancing technology, not a vehicle for developing system capability and preserving it on a shelf. The concept offered by this paper contradicts with Aspin's proposed use of prototyping. In Aspin's rollover strategy, prototyping or rollover develops new technologies and then places them on the shelf for potential future use. Aspin's strategy would take systems through demonstration/validation and then "store" the technology. This approach is characterized as simply not affordable, nor an efficient way of doing business.[33]

The strategy of prototyping should not produce unique hardware for the sole purpose of placing that capability on the shelf until needed. Daniel J. Tellep, Chairperson of Lockheed Corporation, stated "prototypes for prototypes' sake will just produce a lot of museum pieces."[34] The prototyping strategy proposed here does not tie development to any milestone event. Rather, varying levels of prototyping serve as a mechanism to advance technology. How far a new concept is advanced in prototyping depends upon the potential benefit of the technology and its demonstrated performance.

A technology with a demonstrated performance for significant operational utility could be advanced to a limited number of prototypes. This has been call a "silver bullet" prototyping strategy. These limited number prototypes would be provided to the user for operational evaluation and potential operational utilization. These silver bullet prototypes should, however, be viewed as out of the norm due to their unique support requirements.

The degree of funding supporting prototyping of new and emerging technologies should be commensurate with the promise and the risk associated with the technology. Varying degrees of prototyping complexity can promote and prove technology advancements. Those technologies that prove most viable are taken through ever increasing levels of prototyping and ultimately, if performance and operational payback warrants, into production and deployment.

Increased R&D Profit Margins

For contractors to agree to this approach of long-term R&D with no guarantee of follow-on production contracts, there also must be a fundamental change in the Defense Department's approach to profits on research. In the past, contractors used manufacturing as the vehicle to regain funds invested during weapons system R&D. "Contractors tended to absorb losses during research and development, secure in the knowledge they would be made back during long production runs."[35] The government exacerbated this situation by only permitting smaller profits for basic research because it too viewed production as the mechanism for contractors to recover R&D investments. With fewer systems entering into production in the future, alternative incentives are required to motivate contractors into performing the type of quality research that advances technology.

"Cost-type R&D contracts should be structured for at least 15% profit as an incentive for companies to invest their energies and resources in defense RDT&E.

This is typical for commercial contracts, and would likely yield returns of 5% to 10% after subtracting taxes and other non-recoverable costs (such as interest expense). The DoD's technology development efforts are usually riskier than commercial endeavors; thus companies are less assured of an acceptable outcome. The government should be willing to incentivize companies to perform high-quality, innovative R&D work, and to reward them with extra profits when they are successful."[36]

Fewer system concepts entering into full production means there will be additional dollars available to support these increased R&D profits and wider use of prototyping. Specifically, those funds that would have supported manufacturing and system O&M, about 90% of system acquisition costs, are now available for increased R&D. The net effect, however, is an overall saving in procurement accounts.

Maintaining the Industrial Manufacturing Capability

Stimulating R&D represents only half of the problem. Supporting the country's future defense needs also means maintaining the industrial base. There are two functions that assist in maintaining the industrial base while advancing the manufacturing technology. First, there must be an existing manufacturing capability in operation. Production of weapon systems vital to the nation's security should continue at a low-rate. This capability will serve the defense needs both in peace time and in crisis.

Second, enhancements to this production capability are similar to the need to advance technology. If the U.S. manufacturing capability is to remain current, there must be a program, supported by the government, to update facilities and improve its efficiency. Efforts like concurrent engineering and flexible manufacturing provide mechanisms for increasing industrial capacity while

reducing costs through improved efficiency. The government in turn can support these mechanisms by reducing procurement regulations.

Low-Rate Production

The U.S. cannot allow all the manufacturing capability of the defense industrial base to whither away. "Today, it would take approximately three years to reach significantly higher, sustained production rates for almost any major defense system, due primarily to the long lead time needed to obtain unique military-specified parts."[37] There are two reasons for the continuing need of some form of manufacturing capability. First, the need to increase manufacturing output could occur without warning. For the industrial complex to be responsive, there must exist an in-place capability. Second, an existing and functioning production line provides a mechanism for maintaining crucial manufacturing skills. The specialized skills required by the defense industrial base are best maintain by allowing individuals to exercise and use those skills.

This second reason is not a new concept. The maritime industry has long advocated the continued construction of ships to keep the unique skills active. Recent arguments for the Seawolf attack submarine have focused on maintaining specialized submarine construction skills. "Defense Secretary Les Aspin said September 1 (1993) that he wanted to buy a third Seawolf submarine, not because U.S. security requires another one but to keep afloat at least one of the two U.S. shipyards that build submarines."[38]

Secretary Aspin may have had this as his real motive for keeping the F-16 production line open over the objections of the Air Force. Terminating the production line would save $508 million in fiscal year 1994 and $217.3 million in fiscal 1995. Aspin's decision to buy 24 F-16s in fiscal year 1994 preserves 3,000 General Dynamics Corporation jobs in the Dallas-Fort Worth area.[39] While the

politics surrounding this decision clouds the real reason, it is clear that keeping the production line open will preserve aerospace skills. Additionally, it is certainly easier to ramp-up an existing production line vice starting one from scratch.

Concurrent Engineering

If the defense manufacturing process is to remain competitive in a time of declining budgets, it must become more efficient. Concurrent engineering offers a sound methodology for improving the development, manufacturing, and deployment cycle time. The integration of the various disciplines prevalent in weapon system acquisition increases the overall efficiency.

Until the emergence of concurrent engineering, the typical approach to system design involved sequential engineering. In sequential engineering, only one design discipline is active in the process at any one point in time. "In the earliest stages of conceptual design and preliminary development, the design engineers dominate the process. Later, the prototype is handed over to manufacturing so that their engineers can arrange to produce the product on a large scale. After a period of time, procurement experts are involved to ensure that the necessary parts and materials will be available for the assembly process."[40]

A common characteristic of this approach is a lack of systems engineering. Products developed under sequential engineering suffer from poor quality and in the extreme case, they are difficult to manufacture and often do not satisfy the user's needs. These traits affect the overall system cost. As an example, without concurrent engineering, there is an increase in the quantity of engineering changes to the system design. Many of these engineering changes occur well after the manufacturing is underway or even complete. The cost of engineering changes increases logarithmically the later they occur in the product's life cycle.[41]

Additionally, "up to 90% of manufacturing costs may be committed before manufacturing engineers have a say in product design."[42]

Concurrent engineering solves these problems by permitting the separate tasks to take place simultaneously. "Product design, testing, manufacturing and process planning through logistics, for example, are done side-by-side and interactively. Potential problems in fabrication, assembly, support and quality are identified and resolved early in the design process."[43] Utilizing concurrent engineering, development times are reduced by up to 40%.[44] Japan's auto industry use of concurrent engineering is a factor in their ability to "get a new model to market in 3.5 years, a year and a half faster than their American competitors can."[45]

The move towards concurrent engineering has already begun to take place. As shown in Table 1, American companies are beginning to realize the benefits of an approach that was once common place in this country 35 to 80 years ago.[46] As the defense budget continues to decline, adoption of concurrent engineering techniques will allow the industry to remain competitive (responsive) while reducing unnecessary costs.

Flexible Manufacturing

Reductions in the Defense Department's budget translates into fewer new acquisitions. Rather than the long manufacturing runs of the past (production runs lasting several years), future procurements will be limited in quantity. Production techniques that were once profitable in long manufacturing runs now waste considerable dollars. Flexible manufacturing offers one alternative for making short production runs profitable.

A Flexible Manufacturing System (FMS) is "the ability to quickly produce wide varieties of products using the same equipment."[47] The three components of this flexibility are:

1. "The flexibility to produce a variety of products using the same machines and to produce the same products on different machines,
2. The flexibility to produce new products on existing machines, and
3. The flexibility of the machines to accommodate changes in the design of products."[48]

Table 1: Company Results with Concurrent Engineering[49]

Company	Concurrent Engineering Benefits
McDonnell Douglas	• reduced rework costs 29% • reduced scrap costs 57% • reduced nonconformance 38%
AT&T	• reduced process time for a new microprogrammed digital switch by 46%
Boeing	• reduced product development cycle time 40% to 60%
Deere and Co.	• reduced product development time for construction equipment 60% • reduced manufacturing cost by 30% • reduced scrap and rework costs by as much as 75%

Flexible manufacturing or "agile production"[50] is applicable in final assembly productions as well as in the production of individual components. Factories that are small and modular in which the "machinery is reprogrammable to make an almost infinite variety of new or customized goods at low unit cost" are characteristics of FMS.[51] Implemented properly, flexible manufacturing can "approach the efficiencies and economies of scale normally associated with mass production" while only manufacturing a very few products.[52]

Japanese manufacturers are well ahead of those in the United States in the implementation of FMS. Using flexible manufacturing, companies like Nissan can reduce the factory preparation time for a new model from twelve to three months while the existing line continues to operate.[53] This is not to say that flexible manufacturing is unknown to U.S. companies. As listed in Table 2, there are U.S. firms that have increased productivity utilizing FMS.

To realize the full benefits of FMS, U.S. manufactures must not approach this flexibility with a high-volume production mindset. Recent statistics, however, show the U.S. manufacturers continue to hold onto a philosophy of high volume production while implementing FMS. "Equipment utilization for FMSs in the U.S. averages 52 percent compared to 84 percent for the Japanese while the average American machines average production of 10 types of parts pales to the Japanese average of 93 types of parts per machine."[54]

Table 2: Company Results with Flexible Manufacturing[55]

Company	Flexible Manufacturing Benefits
Hughes Aircraft	The FMS was built for 75% of the investment cost, operates at 13% of the labor cost, and will generate the required production at 10% of the machining time cost.
Vought Corporation	The $10 million FMS is expected to save $25 million in machining costs by performing in 70,000 hours work that would take 200,000 by conventional methods.
General Electric	Machining time for multi-ton locomotive engine frame was reduced from 16 days to 16 hours.

Reduced Regulation

Amplifying the potential benefits of the reorientation of the defense industrial base through the incorporation of concurrent engineering and flexible manufacturing requires the relaxation of DoD procurement regulations. This is especially true of FMS since there is an increased opportunity for a single piece of manufacturing equipment to produce both civilian and military components.

Current government regulations require the manufacturing of military components on equipment separate from the civilian components. This is true even if the components are identical. The many regulations, laws, and government practices force companies to develop military products in separate environments. Because of the more than 27,000 specialized military product specifications and

7,000 unique military standards, companies like Boeing, IBM, and Motorola "have established redundant facilities to prevent specialized DoD processes and practices from polluting their commercial operations."[56]

"Defense industry executives have charged that Pentagon procurement policies are continuing to put contractors at inordinate financial risk."[57] Desert Storm provides an example of the roadblocks inherent in the DoD procurement system. The Air Force, short some 6,000 off-the-shelf radios, went to long-time supplier Motorola with the request. To the Air Force's surprise, Motorola denied the request because "government rules required that Motorola set up separate accounting and cost-control systems just to fill the $14 million order—something the company refused to do."[58]

As DoD continues to down size, if the industrial base is to remain responsive to the military's needs, reducing the regulations and requirements would allow a closer relationship between government and commercial work. The Center for Strategic and International Studies identified four regulatory areas that drive "a wedge between the two business: unique cost-accounting requirements and auditing practices; highly specialized military specifications and standards; requirements to provide full technical data rights; and unique and restrictive government contract requirements."[59] Substituting these procurement regulations with common sense business practices provides the industry with the opportunity to be more efficient and responsive. Reducing the regulatory requirements on defense contractors also facilitates the incorporation of improved manufacturing technologies like concurrent engineering and FMS.

Specific Recommendations

In the absence of a new and emerging threat to U.S. sovereignty, reductions to the defense budget can be expected to continue. Keeping the industry viable in this

reduced economic environment means altering the approach to the business of defense. Responsibility for this change rests with both the contractors and the government. There are four specific recommendations.

First, the government must reduce, and where possible eliminate, unnecessary and outdated regulations governing defense procurements. The net affect will be a reduced requirement for government regulators while allowing contractors to utilize best commercial practices to produce produces. Through the use of best commercial practices, contractors will no longer have to develop separate manufacturing and accounting systems for government and civilian products.

Second, there should be an effort to continue to advance both development and manufacturing technology. Development technology can be advanced through a progressive prototyping strategy. This strategy uses varying degrees of prototyping complexity based on the technology's potential promise. The greater the technology benefit, the more encompassing the prototype. Manufacturing technology must also be advanced if the industry is to remain responsive to defense needs.

Third, approaches to system development and manufacturing which promote efficiency and quality should be widely adopted. Concurrent engineering and flexible manufacturing are two approaches which tighten the relationship between development and manufacturing disciplines. This helps reduce system changes which occur late in a development and increase overall costs.

Finally, there needs to be some level of production in existence. This helps sustain the skills necessary in the defense industry while providing the means to accelerate production if the need should arise. Additionally, an existing production run provides a testbed for new manufacturing technologies.

Without an increase in procurement dollars, proper realignment of the defense industry, civilian and government, will allow for maximum use of the available funds. These recommendations only provide guidelines. The specific balance of

technology and production will depend upon the needs of the military and the threats from other countries.

Chapter IV
SUMMARY

At the peak of World War II industrial output, Ford produced 6,792 B-24 Liberators in less than three years at its Willow Run facility.[60] A production capacity of this magnitude is impossible to match in today's military industrial environment. The existing U.S. aerospace industrial complex is undergoing many changes as the U.S. decreases its defense spending. This does not diminish the requirement for a responsive defense industrial base.

The United States has learned many valuable lessons from its participation in past conflicts. In particular, conflict duration since Vietnam has been short. These short-duration conflicts highlight the requirement for a strong military but diminish the opportunity for the introduction of new technologies during the conflict. Two characteristics of the aerospace industry exacerbate these diminished opportunities. First, reductions in defense spending forces a collapse of the aerospace industry that, in turn, reduces production capacity. To compensate for the reduced capacity, the industry has turned to teaming and foreign sources. While each of these solves the near-term problem and improves efficiency, it also increases the U.S. industry's vulnerabilities. Second, the length of time to develop and produce an aircraft has increased, a trend that will continue. This is due in small part to the advanced technology used in new programs.

As the defense department budget continues to decline, if the industrial base is to remain viable, then there must be a change in the overall approach to business. First, the government needs to adopt practices that allow a closer relationship between the contractor's military and commercial work. This is best achieved through reductions in regulatory restrictions. These reductions also would facilitate the infusion of advanced manufacturing technologies like concurrent engineering and flexible manufacturing. These measures taken together would reduce waste

and improve efficiency. Next, in concert with DoD doctrine, efforts to advance technology should continue. A closer integration with the user's needs will help assure these technology efforts are properly focused. Prototyping offers a means of proving the benefits of new emerging ideas before committing large funds to production. For the contractors to continue to provide quality research, allowable profits on R&D should also be increased. Finally, some level of manufacturing capability should remain in existence. This provides the country with a surge capacity while providing a testbed for new manufacturing technologies.

The imminent threat posed by the Soviet Union during the Cold War provided much of the motivation for the size and capability of the military and the industrial complex that supported it. The end of the Cold War opens a window of opportunity for the U.S. to restructure the existing military and the aerospace industry.

NOTES

[1]Marvin Leibstone, "The US Defense Industrial Base: Can it Survive?," *Military Technology*, December, 1991, p. 12.

[2]Robert T. Batcher and John A. Rolando, "Is There Going to be a High-Tech Air Force in the Future?" *Program Manager*, May-June 1992, p. 6.

[3]World War II's start is taken as the Japanese bombing of Pearl Harbor and the end being the their surrender on 15 August, 1945. The Korean conflict begins with the North's invasion of the South on 25 June, 1950, and concludes with the signing of the armistice on 27 June, 1953. The U.S. involvement in Vietnam is harder to pin down since it evolved over time. For this comparison, the Gulf of Tonkin incident on 2 August, 1964, serves as the starting point, since there was a pronounced escalation after the incident as well as Congressional support via the Gulf of Tonkin Resolution. The end of Vietnam is marked by the South's unconditional surrender to the North on 30 April, 1975. The execution of Prime Minister Bishop on 19 October, 1983, marks the beginning of Urgent Fury. The official cessation of hostilities on 2 November, 1983, is used as the end of Urgent Fury. The Presidential order on 17 December, 1989, is used as the start of operation Just Cause. The completion of the troop withdrawals on 13 February, 1990 is used as the end of Just Cause. Finally, the Iraqi invasion of Kuwait on 2 August, 1991, is used as the starting point for Desert Shield. The start of Desert Storm on 17 January, 1991, marks the end of Desert Shield. Desert Storm was completed on 28 February, 1991.

[4]John Newhouse, *War and Peace in the Nuclear Age* (Alfred A. Knopf: New York, 1989), p. 23-50.

[5]Donald I. Blackwelder, *The Long Road to Desert Storm and Beyond* (Maxwell Air Force Base: Air University Press, 1993), p. 13-15.

[6]Blackwelder, p. 25.

[7]Department of Commerce, *U.S. Industrial Outlook '92* (Washington D.C.: U.S. Government Printing Office, 1992), p. 21-1.

[8]Department of Commerce, p. 21-6.

[9]Eric Schine, "Defenseless Against Cutbacks," *Business Week*, January 14, 1991, p. 69.

[10]Eric Schine, "Casualties of Peace," *Business Week*, January 13, 1992, p. 64.

[11]Los Angeles County Aerospace Task Force, "An Economic Adjustment Action Plan the Los Angeles County Aerospace Industry," Los Angeles County, March 17, 1992., p. 2.

[12]Edwin M. Reingold and Bruce van Voorst, "Biting the Bullets," *Time*, April 30, 1990, p. 70.

[13]Bruce B. Auster, "A Healthy Military-Industrial Complex," *U.S. News & World Report*, February 12, 1990, p. 47.

[14]Los Angeles County Aerospace Task Force, p. 2.

[15]Patricia A. Gilmartin, "Administration Officials Say Defense Cuts Will Not Endanger Industrial Base." *Aviation Week & Space Technology*, June 19, 1989, p. 139.

[16]John T. Correll, "A Hole in the Strategy," *Air Force Magazine*, July, 1991, p. 7.

[17]"Design-Build-Field," Development Planning Directorate, Aeronautical Systems Center, Wright-Patterson AFB, OH, 1 August, 1993, p. 30.

[18]"Declassified Photos Show 'Have Blue' F-117A Predecessor," *Aviation Week & Space Technology*, April 22, 1991, p. 30.

[19]Mark Lambert, ed., *Jane's All The World's Aircraft* (Alexandria, VA: Jane's Information Group, 1993-94), p. 506.

[20]Lambert, p. 506.

[21]Lambert, p. 507.

[22]Lambert, p. 497.

[23]Jacques S. Gansler, "Restructuing the Defense Industrial Base," *Issues in Science and Technology*, Spring 1992, p. 52.

[24]Jeffrey A. Drezner, *The Nature and Role of Prototyping in Weapon System Development* (Santa Monica, CA: RAND, R-4161-ACQ, 1992), p. 101.
[25]Drezner, p. 98.
[26]Thomas A. Keaney and Eliot A. Cohen, *Gulf War Air Power Survey Summary Report,* (Air War College, Maxwell AFB, AL), p. 199.
[27]Keaney, p. 68.
[28]Gansler, p. 55.
[29]"Design-Build-Field," p. 39.
[30]"Design-Build-Field," p. 2.
[31]Drezner, p. 9.
[32]Drezner, p. 9.
[33]John D. Morrocco, "Balanced Defense Acquisition Strategy Key to Retaining Healthy Industrial Base," *Aviation Week & Space Technology,* May 25, 1992, p. 59.
[34]Morrocco, p. 59.
[35]Peter Grier, "As Budgets fall, R&D Becomes More Critical," *Government Executive,* August, 1993, p. 119.
[36]"Design-Build-Field," p. 47.
[37]Gansler, p. 52.
[38]Elizabeth A. Palmer, "Substituting for a Sub," *Congressional Quarterly,* September 11, 1993, p. 2403.
[39]Tony Capaccio, "Aspin Decision To Save F-16 In Fiscal 1994 Undercut The Air Force," *Defense Week*, March 1, 1993, p. 3.
[40]M. Carl Ziemke and Mary S. Spann, "Warning: Don't Be Half-Hearted In Your Efforts To Employ Concurrent Engineering," *Industrial Engineering,* February, 1991, p. 45.
[41]Bryan Siegal, "Organizing for a Successful CE Process," *Industrial Engineering,* December, 1991, p. 15.
[42]Spann, p. 45.
[43]John Izuchukwu, "Architecture and Process: The Role of Integrated Systems in Concurrent Engineering Introduction," *Induatrial Management,* March/April, 1992, p. 19.
[44]Emily T. Smith, "Artificial Intelligence Punches in at the Factory," *Business Week,* April 5, 1993, p. 83.
[45]Izuchukwu, p. 19.
[46]Spann, p. 49.
[47]Tony Baer, "Flexible Manufacturing, It's Gotten Easier to Change on Demand," *Computerworld,* February 11, 1991, p. 59.
[48]R. Anthony Inman, "Flexible Manufacturing Systems: Issues and Implementation," *Industrial Management,* August 1991, p. 7.
[49]Izuchukwu, p. 21.
[50]Thomas A. Stewart, "Brace for Japan's Hot New Strategy," *Fortune,* Septmeber 21, 1992, p. 63.
[51]Stewart, p. 63.
[52]Inman, p. 8.
[53]Stewart, p. 72.
[54]Inman, p. 9.
[55]Inman, p. 8-9.
[56]Gansler, p. 51.
[57]Anthony L. Velocci, Jr., "Pentagon Procurement Policies Remain Sore Point With Defense Industry Officials," *Aviation Week & Space Technology,* July 1, 1991, p. 41.
[58]Mike Mills, "Giving Contractors a Break," *Congressional Quarterly,* October 30, 1993, p. 2947.
[59]Gansler, p. 54.

[60]Allan G. Blue, *The B-24 Liberator, A Pictorial History* (Charles Scribner's Sons, New York), p. 37.

BIBLIOGRAPHY

1. Auster, Bruce B., "A Healthy Military-Industrial Complex" *U.S. News & World Report*, February 12, 1990.

2. Baer, Tony., "Flexible Manufacturing, It's Gotten Easier to Change on Demand," *Computerworld*, February 11, 1991.

3. Batcher, Robert T. and Rolando, John A., "Is There Going to be a High-Tech Air Force in the Future?" *Program Manager*, May-June 1992.

4. Blackwelder, Donald I., *The Long Road to Desert Storm and Beyond, The Development of Precision Guided Bombs:* Maxwell Air Force Base: Air University Press, 1993.

5. Blue, Allan G., *The B-24 Liberator, A Pictorial History*, Charles Scribner's Sons, New York.

6. Capaccio, Tony., "Aspin Decision To Save F-16 In Fiscal 1994 Undercut The Air Force," *Defense Week*, March 1, 1993, p. 3.

7. Correll, John T., "A Hole in the Strategy," *Air Force Magazine*, July, 1991.

8. "Declassified Photos Show 'Have Blue' F-117A Predecessor," *Aviation Week & Space Technology*, April 22, 1991.

9. Department of Commerce., *U.S. Industrial Outlook '92*: Washington D.C.: U.S. Government Printing Office, 1992.

10. "Design-Build-Field," Development Planning Directorate, Aeronautical Systems Center, Wright-Patterson AFB, OH, August 1, 1993.

11. Drezner, Jeffrey A., *The Nature and Role of Prototyping in Weapon System Development*, Santa Monica, CA: RAND, R-4161-ACQ, 1992.

12. Gansler, Jacques S., "Restructuing the Defense Industrial Base," *Issues in Science and Technology*, Spring 1992.

13. Gilmartin, Patricia A., "Administration Officials Say Defense Cuts Will Not Endanger Industrial Base." *Aviation Week & Space Technology*, June 19, 1989.

14. Grier, Peter., "As Budgets fall, R&D Becomes More Critical," *Government Executive*, August, 1993.

15. Inman, R. Anthony., "Flexible Manufacturing Systems: Issues and Implementation," *Industrial Management*, August 1991.

16. Izuchukwu, John., "Architecture and Process: The Role of Integrated Systems in Concurrent Engineering Introduction," *Induatrial Management*, March/April, 1992.

17. Keaney, Thomas A. and Cohen, Eliot A., *Gulf War Air Power Survey Summary Report,* Air War College, Air University, Maxwell AFB, AL.

18. Lambert, Mark, ed., *Jane's All The World's Aircraft*. Alexandria, VA: Jane's Information Group, 1993-94.

19. Leibstone, Marvin., "The US Defense Industrial Base: Can it Survive?," *Military Technology,* December, 1991

20. Los Angeles County Aerospace Task Force, "An Economic Adjustment Action Plan the Los Angeles County Aerospace Industry," Los Angeles County, March 17, 1992.

21. Mills, Mike., "Giving Contractors a Break," *Congressional Quarterly,* October 30, 1993.

22. Morrocco, John D., "Balanced Defense Acquisition Strategy Key to Retaining Healthy Industrial Base," *Aviation Week & Space Technology,* May 25, 1992.

23. Newhouse, John., *War and Peace in the Nuclear Age*: New York: Alfred A. Knopf, 1989.

24. Palmer, Elizabeth A., "Substituting for a Sub," *Congressional Quarterly,* September 11, 1993.

25. Schine, Eric., "Casualties of Peace" *Business Week,* January 13, 1992.

26. Schine, Eric., "Defenseless Against Cutbacks" *Business Week,* January 14, 1991.

27. Siegal, Bryan., "Organizing for a Successful CE Process," *Industrial Engineering,* December, 1991.

28. Smith, Emily T., "Artificial Intelligence Punches in at the Factory," *Business Week,* April 5, 1993.

29. Spann, Mary S. and Ziemke, M. Carl., "Warning: Don't Be Half-Hearted In Your Efforts To Employ Concurrent Engineering," *Industrial Engineering,* February, 1991.

30. Stewart, Thomas A., "Brace for Japan's Hot New Strategy," *Fortune,* Septmeber 21, 1992.

31. Velocci, Jr., Anthony L., "Pentagon Procurement Policies Remain Sore Point With Defense Industry Officials," *Aviation Week & Space Technology,* July 1, 1991.

32. van Voorst, Bruce and Reingold, Edwin M., "Biting the Bullets" *Time,* April 30, 1990.

REFERENCES

1. Brown, David A. "Defense Base Erosion Could Hurt Military Aircraft Exports" *Aviation Week & Space Technology,* March 2, 1992.

2. "Caveat Protector" *The Economist,* May 16, 1992.

3. "Defense Cuts Deliver a Body Blow to Factory Jobs" *Business Week,* June 17, 1991.

4. Gerwin, Donald. "Manufacturing Flexibility: A Strategic Perspective" *Management Science,* April, 1993.

5. Hensley, David. "Impacts of Northrop's F-23 and B-2 Aircraft Programs on the California Economy" Final Report, John E. Anderson Graduate School of Management, University of California, Los Angeles, April 15, 1991.

6. "Protecting the Defense Industrial Base" *Aviation Week & Space Technology,* February 11, 1991.

7. "Prototype-Only Strategies Criticized" *Defense Electronics,* October, 1992.

8. "Saturn Gets High Volume and Flexibility from LeBlond Makino Cells" *Industrial Engineering,* October 1992.

9. Sánchez, Angel M. "Flexible Automation and High Technology in the U.S. Metalworking Industry" *Management International Review,* Vol. 31, 1991.

10. Weidenbaum, Murray.*Small Wars Big Defense.* New York: Oxford University Press, 1992.